(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 April 2004 (22.04.2004)

PCT

(10) International Publication Number
WO 2004/034669 A1

(51) International Patent Classification[7]: H04L 29/06

(21) International Application Number:
PCT/EP2003/050704

(22) International Filing Date: 8 October 2003 (08.10.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
02292485.6 9 October 2002 (09.10.2002) EP

(71) Applicant *(for all designated States except US)*: MOTOROLA INC [US/US]; 1303 E.Algonquin Road, Schaumburg, IL 60196 (US).

(72) Inventors; and

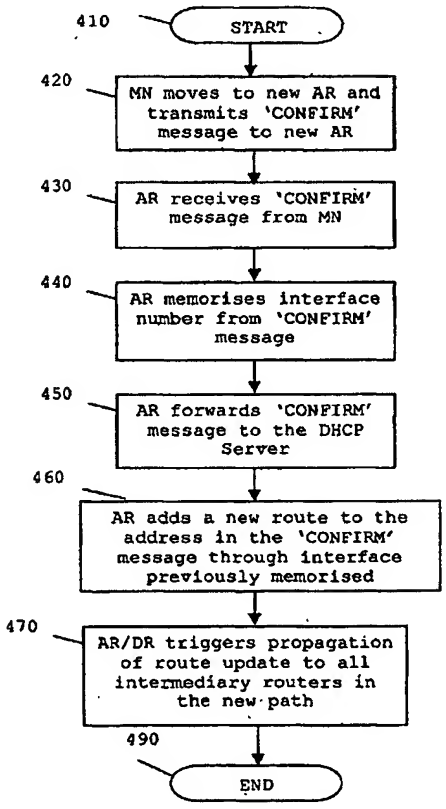
(75) Inventors/Applicants *(for US only)*: PETRESCU, Alexandru [FR/FR]; Motorola SAS, Parc des Algorithmes, Saint Aubin, F-91193 Gif-Sur-Yvette (FR). JANNETEAU, Christophe [FR/FR]; Motorola SAS, Parc des Algorithmes, Saint Aubin, F-91193 Gif-Sur-Yvette (FR). LACH, Hong-Yon [FR/FR]; Motorola SAS, Parc des Algorithmes, Saint Aubin, F-91193 Gif-Sur-Yvette (FR).

(74) Agent: MCCORMACK,, Derek J.; Motorola European Intellectual Property Operations, Midpoint, Alencon Link, Basingstoke, Hampshire RG21 7PL (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK,

[Continued on next page]

(54) Title: ROUTING IN A DATA COMMUNICATION NETWORK



(57) Abstract: A method of supporting mobility (400, 500) in an Internet Protocol (IP)-based data network. The method comprises the steps of generating a first stateful IP autoconfiguration message at a mobile node, whereby the message includes an address capable of use for routing maintenance. The mobile node transmits, the generated message to a first access node (240), which incorporates its address and forwards the message to a dynamic host configuration protocol (DHCP) Server. The DHCP Server (320) and access node (240) analyse the message to determine a route to deliver data to and/or from the mobile node. One or more route update message are triggered from said access node and said DHCP server to a number of network elements (230) between said access node and said DHCP server in the IP based data network to support mobility in an IP domain with minimum bandwidth use and minimum tunnelling required. A DHCP Server (320) and an access node (250) such as DHCP Relay are also described. In this manner, the inherent configuration flexibility of stateful autoconfiguration addresses is provided, in contrast to, say, other micro-mobility management schemes where the IP address is manually configured.

WO 2004/034669 A1

MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

ROUTING IN A DATA COMMUNICATION NETWORK

Field of the Invention

This invention relates to data flow in communication and computer networks. The invention is applicable to, but not limited to, an addressing/routing mechanism for mobile nodes within such networks.

Background of the Invention

The Internet is becoming more and more popular, with access to the Internet being provided via computer networks and communication networks. The standard communication mechanism that communication units use to access the Internet is the well-known Internet Protocol (IP) version 4 and version 6.

Indeed, users increasingly wish to access the Internet whilst on the move via their mobile communication device(s). These devices are termed mobile nodes in IP-parlance. Different types of mobile nodes may be employed for this purpose, for example, a portable personal computer (PC), a mobile telephone or a personal digital assistant (PDA) with wireless communication capability. Furthermore, mobile users are accessing the Internet via different types of fixed or wireless access networks, for example a cellular radio communication network, such as a Universal Mobile Telecommunication System (UMTS) network, a HiperLAN/2 or IEEE 802.11b local area network, a Bluetooth™ local communication system, or fixed accesses such as the Ethernet, and so on.

It is currently possible to support handover accessing of the Internet from one access network to another, for example by using a protocol known as Mobile-IP. Traditional mobility support aims to provide continuous Internet connectivity to mobile hosts, thereby allowing individual mobile users to connect to the Internet whilst being mobile by providing the mobile host with the opportunity to move the location of their Internet access. Recently, there has been a significant amount of interest and research in the Mobile IPv6 specification, as described in the document co-authored by David B. Johnson: IETF Internet-Draft draft-ietf-mobileip-ipv6-18.txt, June 2002.

Within IPv6 networks, host devices and client devices are allocated addresses comprising a hundred and twenty-eight bits to identify the device to other devices within, or external to, the network. The one hundred and twenty-eight bit addresses are known as Internet Protocol version 6 Addresses (IPv6 addresses). In the following, the terms IPv6 addresses and IP addresses are used inter-changeably. IP addresses provide a simple mechanism for identifying the source and destination of messages sent within IP networks.

Traditionally, IP addresses that identify devices within IP networks have been assigned in a static manner during network configuration. Using this type of static assignment, data routers and other network components are pre-configured to use the statically assigned address bindings that correlate devices to their IP addresses.

However, in large or rapidly changing networks, static assignment of IP addresses is often inadequate. As a

result, several methods have been developed that allow IP addresses to be automatically assigned. The two widely used methods include:

(i) Automatic distribution by central servers, and

(ii) Address derivation by a close cooperation between hosts and the immediately neighbouring router.

In another method employed in some IP networks, routers analyse IP data packets received from client devices. Every data packet has a source address and a destination address. The source addresses in these data packets are extracted and used to update routes within the router to deliver data packets to and/or from particular devices. In those latter types of networks routes are updated based on the packets circulating within the network, but addresses are not automatically assigned.

A tunnelled packet is a data packet that encapsulates within it another data packet. Thus, the encapsulating data packet has a pair of source and destination addresses. A further encapsulated packet has additional source and destination addresses, and so on. Such a tunnelling mechanism allows a Home Agent to keep track of the current position of a Mobile Node and forward packets from the home position (designated by an IP address, or Home Address) to the new position (a new IP address, or the Care-of Address). From a routing perspective, tunnelling allows a route of the data packet to be determined, e.g. by de-tunnelling the data packets to determine the source address of each encapsulated packet.

Increasingly, IP addresses within networks are assigned by server systems using the Dynamic Host Configuration

Protocol (DHCP) as is defined in Internet RFC 1541, which is incorporated herein by reference. For networks that use the DHCP protocol, one or more DHCP servers are configured to listen for messages requesting IP addresses. If possible, the DHCP server then allocates an IP address to the client system that sent the message. The newly allocated IP address is then included in a message sent by the DHCP server to the client system. The IP address is, in effect, provided to the client system on a time-limited basis, thereby allowing reuse of the same addresses by the same or a different client.

In general, the use of DHCP servers to assign IP addresses to client systems has proven to be particularly advantageous, saving non-expert users from manipulating long strings of digits (IP addresses). Furthermore, it allows an administrator tight control over the management of the address pool and guarantees the uniqueness of each used address. This is especially true in networks that include a large number of client systems.

Referring now to FIG. 1, a known IP routing mechanism is described that employs the IETF Mobile IPv6 protocol in a network. As an example, a network that is frequently found in a campus-type mobility network is shown. The network uses link technologies such as Ethernet and 802.11b.

In this regard, a mobile node 160 is operating in a micro-mobility (local-mobility) computer/ communication domain. The micro-mobility computer/ communication domain is configured as a tree structure, with a gateway 120 between nodes in the local domain and, say, the Internet 110. For example, let us assume the mobile node

is a portable computer that is able to communicate with the Internet 110 by wirelessly coupling to any of a number of access points/access routers 140-150.

The access routers are typically coupled to Dynamic Host Configuration Protocol (DHCP) Relays. The routing functionalities (in software) and the DHCP Relay functionalities (in software) are executed within the same access node. Optionally, the two functionalities can be spread over two different nodes, but with the restrictions that:

(i) The Relay must be placed on the link immediately next to the mobile node in order to receive the broadcasted address autoconfiguration messages sent by the mobile node, and

(ii) The Router functionality must be placed as far as possible towards the edge of the local mobility domain in order to ensure correct propagation of routes.

The micro-mobility domain includes routers 130, 132, 134 to link the access routers/DCHCP relays 140-150 to the gateway that includes a DHCP server 120. When the mobile node 160 has logged on to access router 140, it is assigned a temporary IP address, which is informed 165 to the MN's Home Agent 105. The MN 160 is able to access applications from application server 115, via a route 170 that encompasses the Internet 110, the gateway/DHCP server 120, and a number of serially-coupled intermediate routers 130 (with only one router shown) and the access router 140.

Notably, when the MN 160 logs on to another access router/DHCP relay 150, a new IP address is allocated to

the MN. The new IP address is informed in message 175 to the MN's Home Agent 105 so that communication towards the home position (home address) of the MN can be routed to the new position of the MN 160 (Care-of Address). In this regard, a skilled artisan would appreciate that a network that employs an IETF Mobile IPv6 protocol is not ideally suited for managing a micro-mobility (or local mobility) domain. The unsuitability emanates from a high control overhead resulting from frequent notifications to the Home Agent 105.

Methods that use DHCP and Mobile IP to manage mobility at an IP level are described in the documents by Charles E.Perkins, et al.:

(i) "Using DHCP with Computers that Move", Proceedings of the Ninth Annual IEEE Workshop on Computer Communications, 1994; and

(ii) "DHCP for Mobile Networking with TCP/IP", Proceedings of the IEEE Symposium on Computers and Communications, 1995.

DHCP is used to dynamically obtain a Care-of-Address (CoA) that will subsequently be registered with a Home Agent. In this manner, a Home Agent builds and maintains IP tunnels that deliver packets to mobile nodes through the routers 130, 132, 134.

A significant problem with mobile nodes is the requirement to assign new CoAs as and when the mobile node accesses the network via a different access point. Furthermore, the tunnelling requirement in such IP systems, particularly in a micro-mobility domain, has been appreciated by the inventors of the present invention as a further significant disadvantage.

US005812819A, titled "Remote Access Apparatus and Method which Allow Dynamic Internet Protocol (IP) Address Management", describes a mechanism to use the same CoA whilst changing points of attachment. The primary focus of US005812819A is to use a unique personal identifier, such that with each re-connection, a user obtains the same CoA. However, although US005812819A describes the maintenance of the same CoA, the mechanism still requires, and therefore suffers from the disadvantages of, inter-domain tunnelling by a Home Agent of Mobile IPv6.

'Address auto-configuration protocols' have been identified as an important requirement for IP mobile nodes in the following documents:

(i) Dynamic Host Configuration Protocol for IPv6 (DHCPv6), Internet Draft, draft-ietf-dhc-dhcpv6-19.txt; and

(ii) "DHCP for IPv6" by Charles E. Perkins, et al. Bound, and published at the Third IEEE Symposium on Computer and Communications, 1998.

The reasons identified for address auto-configuration protocols being an important requirement for IP mobile nodes include:

(a) Due to the wide Internet penetration having led to the Transport Control Protocol (TCP)/IP stack to be deployed in general-purpose computing machines, the user of such a machine rarely has the skill (or the desire) to manually configure its TCP/IP stack.

(b) With the advent of smaller and ubiquitous devices, it is often the case that there is no user to

configure the device stacks: they must be configured as Plug-n-Play.

In IPv6 there exist two address autoconfiguration mechanisms: 'stateless' and 'stateful'. The important difference between these two mechanisms is that stateful autoconfiguration uses a pair of hosts (server and relay) to maintain an address database as well as to relay a node's request and relay replies in the allocation of an address across a network. In stateless autoconfiguration the message exchange for autoconfiguration is limited to one link and there is no state to maintain.

WO9826549, titled "Method for Using DHCP to Override Learned IP Addresses in a Network", describes a method whereby DHCP messages are scanned for IP assignment events. When an event is triggered, a pre-configured IP route is updated in a central 'router' table.

Each route provides a mapping between an IP address and a client system. When the router receives an IP packet, it extracts the destination address of the packet from the packet's header. The router then searches the route table for a route that matches the destination address of the received IP packet. If the router finds a matching route, the router forwards the IP packet to the client system included in the matching route.

Notably, the method is applicable in a dialup environment, where all clients connect to one router and all accessed servers are situated directly connected on the same router. Hence, the applicability of WO9826549 is very limited.

Using the DHCP protocol, client systems request and receive dynamically allocated IP addresses from the DHCP server systems. The router listens for DHCP ACK messages sent by DHCP server systems to the client systems. The DHCP ACK message includes an IP address that has been allocated to a specific client system. When the router detects a DHCP ACK message, the router extracts the IP address allocated for the client system. Using the IP address included in the DHCP ACK message, the router "learns" the IP address of the client system requesting an IP address. The router then adds the route to its route table. The new route is marked to indicate that the DHCP server has assigned it. Thereafter, the router will only relearn this IP address if it is reassigned by the DHCP server system.

In some cases, the learned IP address will conflict with a route originally configured within the router's route table. In these cases, the conflicting route is removed from the route table. In this way, WO9826549 allows routes that reflect dynamically allocated IP addresses to replace already configured routes. The inventors of the present invention have recognised and appreciated the limitations of this method in that it is only able to update routers with new IP routes and is inadequate to handle new IP routes in a network scenario.

Moreover, the method provides for updates within only one "central" router, where all clients and servers are connected and using it as a unique "central" node of communication. It is known that such star networks are not implementable for large systems with hundreds of clients and thousands of servers. The inventors of the present invention have recognised a need to provide for

route updates within an entire cloud of routers, where everything is connected in a mesh-like topology, scaling the number of routes to connect any number of clients and servers.

US6249523, titled "Router for which a Logical Network Address which is not Unique to the Gateway Address in Default Routing Table Entries", presents a method to update ARP cache entries, effectively "routing" in a local broadcast link only, when triggered by DHCP messages.

EP 1011241 discloses a scheme for route update within a local mobility domain. EP 1011241 considers initial assignment of the Care-of Address in the local mobility domain by DHCP. EP 1011241 discloses a protocol entirely designed for route updates with IPv4, which cannot be applied to IPv6. Furthermore, as in other scenarios, EP 1011241 only discloses triggering of a single route update message from a base station at 'start-up' or from a mobile node when entering a visited domain.

It is noteworthy that the document titled "Cellular IPv6, Internet Draft Personal Proposal", draft-shelby-seamoby-cellular-ipv6-00.txt. describes a mechanism to manage IP mobility within a domain by appropriately updating per-host IP routes. Cellular IPv6 is a new protocol, which has been pending standardization for a number of years. Cellular IPv6 is equivalent to other routing protocols such as RIP. One of the reasons that Cellular IP has yet to be accepted for standardization is its use of paging concepts, which are natural in a 3GPP environment. However, such concepts are unfeasible with IP protocols, due to architectural inefficiencies such as network

flooding (broadcast) of periodic (time-triggered) data over a large number of networks. Furthermore, the route status in this document is limited to a "personal proposal". As such, the mechanism is inadequate for standard IP mobility scenarios.

In summary, the inventors of the present invention have recognised that present implementations of IPv6 suffer from the need to regularly signal to remote home agents when a mobile node is mobile, for example, continuous updating of the mobile node's CoA. Furthermore, IPv6 introduces problems in tunnelling requirements, when some configurations may not necessarily need to incur such complex and bandwidth/throughput costly mechanisms. Current attempts at resolving one or more of the above problems have a consequent effect on other IP protocols.

Statement of Invention

In accordance with a first aspect of the present invention, there is provided a method of supporting mobility in an Internet Protocol (IP)-based data network, as claimed in Claim 1.

In accordance with a second aspect of the present invention, there is provided an access node such as a DHCP Relay, as claimed in Claim 9.

In accordance with a third aspect of the present invention, there is provided a DHCP Server, as claimed in Claim 10.

In accordance with a fourth aspect of the present invention, there is provided a data communication network, as claimed in Claim 16.

In accordance with a fifth aspect of the present invention, there is provided an IPv6 communication message, as claimed in Claim 20.

In accordance with a sixth aspect of the present invention, there is provided a storage medium, as claimed in Claim 21.

In accordance with a seventh aspect of the present invention, there is provided an apparatus, as claimed in Claim 22.

In accordance with an eighth aspect of the present invention, there is provided a communication unit, as claimed in Claim 23.

In accordance with a ninth aspect of the present invention, there is provided a data communication network, as claimed in Claim 24.

Further aspects of the present invention are as claimed in the dependent Claims.

In summary, the preferred embodiment of the present invention describes a mechanism to manage IPv6 local mobility without requiring any tunnelling of data messages towards a remote Home Agent. The mechanism utilises address autoconfiguration mechanisms capable of use in route maintenance. Advantageously, route update messages may be sent from both a DHCP Server and an

access node such as a DHCP Relay when new IP routes are determined. Preferably, old or unacceptable IP routes are deleted within the local mobility. The method is able to use standard IETF protocols, such as DHCPv6 and RIP.

Brief Description of the Drawings

FIG. 1 illustrates a known computer/communication mobile network and mechanism for communicating to a mobile node.

Exemplary embodiments of the present invention will now be described, with reference to the accompanying drawings, in which:

FIG. 2 illustrates a computer/communication mobile network adapted to implement the preferred embodiment of the present invention;

FIG. 3 illustrates a Dynamic Host Configuration Protocol (DHCP) Server adapted to implement the preferred embodiment of the present invention;

FIG. 4 illustrates a flowchart of a process implemented by an access router DHCP Relay according to the preferred embodiment of the present invention; and

FIG. 5 illustrates a flowchart of a process implemented by a DHCP server, according to the preferred embodiment of the present invention.

Description of Preferred Embodiments

Referring now to FIG. 2, a network configuration is illustrated in accordance with the preferred embodiment of the present invention. The network configuration preferably employs the IETF Mobile IPv6 protocol. As an example, a network that is frequently found in a campus-type mobility network is shown. The network uses link technologies such as Ethernet and 802.11b.

The preferred network topology, as illustrated in FIG. 2, is a tree-type structure as known to those skilled in the art. However, although the preferred embodiment is described with reference to a tree-type structure, the inventive concepts described herein are equally applicable to any mesh-type structure. Conceptually, the root of the tree corresponds to the DHCP server (DS), with the MN movement managed only by the leaves of the tree. The preferred embodiment shows the last hops as using wireless access media, to communicate to the mobile nodes, although any access mechanism is acceptable (including dialup and other wired accesses like DSL, or plain Ethernet).

It is also assumed, in the context of the preferred embodiment of the present invention, that each access router (AR) is co-located with a DHCP relay (DR), and the Internet Gateway with the DHCPv6 Server respectively. All intermediate routers are normal routers.

In this regard, a mobile node 160 is operating in a micro-mobility (local) computer/communication domain. The micro-mobility (local) computer/communication domain is configured as a tree structure, with a gateway 220 between nodes in the local domain and, say, the Internet 110. For example, let us assume the mobile node is a

portable computer that is able to communicate with the Internet 110 by wirelessly coupling to any of a number of access points/access routers 240-250.

The micro-mobility domain includes routers 230, 232, 234 linking the access routers/DCHCP relays 240-250 to the gateway that includes a DHCP server 220. When the mobile node 160 has logged on to access router 240, it is assigned a temporary IP address, which is informed 165 to the MN's Home Agent 105. The MN 160 is able to access applications from application server 115, via a route 170 that encompassed the Internet 210, the gateway/DHCP server 220, and a number of arbitrarily, or mesh-coupled intermediate routers 230 (with any number of intermediate routers on each path shown) and the access router 240.

Notably, in accordance with the preferred embodiment of the present invention, when the MN 160 logs on to another access router/DHCP relay 250, the same IP address is used. In this regard, when a MN changes its point of attachment between two Access Routers (AR), say AR 240 and AR 250, it confirms its previously acquired address to the DHCPv6 Server (DS) 220 via the DHCPv6 Relay (DR) co-located with the current AR 250. A 'CONFIRM' message then triggers an updating of routes in the DS 220, from the path towards the previous AR 240, to the path towards the new AR 250 with the route including all of the corresponding intermediate routers 234. A new route is therefore added to the address within the message by the access router/DHCP relay 250. The 'CONFIRM' message is concurrently relayed to the DS 220.

Instead of passing on a potentially new CoA for the new route to the Home Agent 105 of the MN 160, the DS 220

effectively receives the 'CONFIRM' message from the DR containing the same CoA (the "confirmed" address) and updates its routing table. In this manner, any new messages for MN 160, coming from the Internet 110 and sent via the gateway/DHCP server 220 are intercepted and re-routed to the new address, thereby not following the old route.

Thus, it is envisaged that any access node, for example a dynamic host configuration protocol (DHCP) Relay 250 includes a receiving function receiving at least one Internet Protocol (IP) message from a mobile node, wherein the IP message includes a mobile node address capable of use for route maintenance to deliver data to and/or from the mobile node. The access node also includes a processor, operably coupled to the receiving function, to intercept and analyse the IP message, and determine a route to deliver data to and/or from the mobile node. The access node 250 triggers a transmission of one or more route update messages from via a number of network elements (such as intermediate routers 230 between said access node to a DHCP server in the IP based data network.

Preferably, the old route is deleted; once the gateway/DHCP server 220 has accepted the new route to the MN 160, in order to correctly forward packets coming from inside the local-mobility domain.

The networking protocols are based on IPv6 and as such employ IPv6 stateful address autoconfiguration (i.e. DHCPv6) and a distance-vector routing protocol. A preferred distance-vector routing protocol, such as Triggered Routing Information Protocol (RIP), is used.

In this regard, the DHCP CONFIRM message is used to trigger the Triggered RIP.

Autoconfiguration:

A stateful autoconfiguration mechanism is selected as the presence of a DR and DS 220 at the extremities of the micro-mobility routing domain allows tight control of routing path updates. In the stateless case, the routing path update(s) can only be triggered by one end of the routing path, i.e. the AR 250.

A particular message exchange deals with the renewal (or release thereof) of an already allocated IPv6 address of an MN when this moves to a new link. The message exchange tracks the following process: upon detection of movement and after attaching to a new AR 250, the MN 160 generates a CONFIRM message containing various identifiers of its configured interfaces, among which it uses the address it had used when first configuring this interface with a server. The CONFIRM message is sent to the DR (supposedly co-located with the new AR) and next propagated to the DS 220. Following reception of the 'CONFIRM' message, the DS 220 generates a 'REPLY' message to send to the MN 160 through the corresponding DR. In this way, the DHCPv6 transaction is completed and the MN 160 can continue to use the originally allocated address within the new subnet under the new AR 250.

Triggering Mechanism:

The preferred triggering mechanism is a set of processor-implementable instructions (i.e. software) that couples the interpretation of DHCP messages (CONFIRM by DS and DR

and ACK for DR) with RIP messages (Unsolicited Route Updates). The reception and interpretation of standard DHCP messages is enhanced to launch standard RIP messages. Routing Information Protocol (RIP) is a standard distance-vector algorithm for exchanging routing messages and computing routes within an Administrative Domain.

The preferred embodiment of the present invention is independent of the underlying per-host routing protocol, and employs a slight modification of RIP such that the protocol:

(i) Includes standard RIP v2 features;

(ii) Includes standard Triggered RIP extensions;

(iii) Includes standard RIPing extensions, since this is an IPv6 environment;

(iv) Provides periodic updates by transmitting entire routing tables are entirely removed; and

(v) Propagates updates of per-host routes upon reception of Triggered update.

Traditionally, IP routing protocols are designed with no specific topology assumptions. In such circumstances, the underlying model assumes that the connectivity among routers takes the form of, say, a graph and links periodically fail and come up. A routing protocol is designed such that the network as a whole survives this kind of interruption.

In this manner, the network provides IP mobility within a local mobility domain by setting up and maintaining IP routes. When a MN changes its point of attachment between two Access Routers (AR) it confirms its

previously acquired address to the DHCPv6 Server (DS) via the DHCPv6 Relay (DR) co-located with the current AR. The CONFIRM message triggers the launch of Triggered Route Updates, thus changing the routes in the DS, the previous AR, the new AR and in all intermediate routers.

A skilled artisan would recognise that the number of elements shown in the network of FIG. 2 are limited for clarity purposes only. Furthermore, it is within the contemplation of the invention that other network configurations and inter-coupling of elements can be used.

Advantageously, the inventors of the present invention have recognised and appreciated the wider benefits offered by dynamically building and maintaining per-host routes within a small micro-mobility domain. In particular, the inventors have identified that per-host routing, which has traditionally been implemented for large-sized networks such as the Internet that spans continents and supports large-size of routing tables and very frequent updates of a large number of mobiles), is more appropriate than using tunnels due to the:

(i) Simplicity of routing protocols and wide availability of implementations;

(ii) More efficient use of bandwidth, otherwise used to encapsulate packets in a tunnelling mechanism;

(iii) Avoidance of a need to introduce entirely new protocol entities (local mobility agents); and

(iv) Relatively minor adaptation of existing routers and DHCPv6 servers, as described below.

Hierarchical Mobile IPv6 schemes, as described by: Claude Castellucia, in "A Hierarchical Mobile IPv6 Proposal", of the 4th ACTS Mobile Communications Summit, 1999 and David B. Johnson and Charles E. Perkins in Hierarchical Foreign Agents and Regional Registration, Minutes of the Mobile IP working group meeting, 35th IETF, March 1996. The inventive concepts of the present invention provide two important benefits over known Hierarchical Mobile IPv6 schemes:

(i) Bandwidth savings by eliminating tunnels.

(ii) Elimination of local mobility management entities (e.g. MAP) that have been pending IETF standardization for several years.

(iii) Use of the same CoA within the entire local-mobility domain (HMIP changes the CoA, but does not propagate the change up to the distant home agent (HA). Advantageously, the inventive concepts described herein not only avoid propagating the CoA to HA, but maintain the same CoA).

When compared to all other micro-mobility (or local mobility) management schemes, the inventive concepts herein described provide:

(i) The inherent configuration flexibility of stateful autoconfiguration, whereas the other micro-mobility management schemes all suppose the IP address is manually configured;

(ii) Ability to implement a more rapid propagation of route updates by triggering, in a substantially simultaneous manner, route updates from two separate points of the tree, namely the DS and the DR,

whereas other micro-mobility management schemes trigger the route update from one point only; and

(iii) The process of the present invention is able to use standard IETF protocols.

Referring now to FIG. 3, a Dynamic Host Configuration Protocol (DHCP) Server 310 adapted in accordance with the preferred embodiment of the present invention, is illustrated. The DHCP Server 310 includes a signal processing function 320 operably coupled to a receiving function 325 and a memory element 330. The memory element comprises a router processing function 340 and a route table 350. The DHCP Server 310 communicates to other devices in the network via an input port 360 and an output port 370. The DHCP Process uses a DHCP Address Table to keep track of assignments of addresses to mobiles, as well as approving and denying requests.

In accordance with the preferred embodiment of the present invention, the receiving function receives at least one first Internet Protocol message from a mobile node through a first access node, as described above. The at least one first Internet Protocol message comprises an address that is used to build a data route to deliver data to and/or from the mobile node via the first access node. The signal processing function 320 processes the first Internet Protocol message to determine the data route to/from the mobile node, and stores the route information.

The DHCP Server 310 has been adapted to receive at least one second Internet Protocol message from the mobile node through a second access node, such that the second Internet Protocol message comprises an address used to

build a second data route. The signal processing function 320 then determines whether the second data route is the same as the stored first data route. In response to the determination, the DHCP Server 310 triggers a message to all its neighbour routers and subsequently to all routers in the routing domain deleting the first data route if the second route is accepted. Alternatively, the DHCP Server 310 triggers a message to the second access node deleting the second data route, if the new route is not accepted.

Preferably, the first and second Internet Protocol messages are IPv6 messages such as IPv6 stateful autoconfiguration 'CONFIRM' messages. In an enhanced embodiment of the present invention, the signal processing function 320 intercepts DHCPv6 stateful autoconfiguration IP messages sent from mobile nodes via ARs and processes the message to determine a new data route to deliver data to and/or from the mobile node. In response, the new route is used to update the data route in the router table in response to the processed DHCPv6 stateful autoconfiguration IP message. The signal processing function 320 then sends a delete route message to network elements in the data route to update their route records.

Referring now to FIG. 4, a flowchart 400 illustrates a preferred operation of the Access Router. It is assumed that the MN has already configured an address for its interface with a normal DHCPv6 transaction, as described above with respect to FIG. 2. Furthermore, it is assumed that the MN is currently active within a sub-network, whilst its routing address indicates access to/from the

MN via the old AR. The mobile node has previously confirmed this old address to the DS through the DR.

The operation of the new AR starts in step 410. The MN moves to a new AR. The MN generates a 'CONFIRM' message and transmits this message to the new AR as shown in step 420. Upon reception of the CONFIRM message in step 430, the AR memorises the interface address from which it received the 'CONFIRM' message, in step 440.

The DR (operably coupled to the AR) routes the 'CONFIRM' message up to the DS, as shown in step 450. In addition, the DR also adds a new route to this address through the (memorised) interface address that received the 'CONFIRM' message, as in step 460. This route addition to the 'CONFIRM' message is propagated up-stream to all intermediary routers in the new path to the DS, preferably by means of Unsolicited Route Update messages, as shown in step 470. In this manner, the MN has moved to a new access point and a new route to the MN has been generated by the AR/DR in the 'CONFIRM' message sent to the DS.

Referring now to FIG. 5, a flowchart 500 illustrates a preferred operation of the DHCPv6 Server (DS), in response to receiving a 'CONFIRM' message with a new route update from the AR/DR as described above with respect to FIG. 4.

The DS operation starts in step 510. Upon reception of the 'CONFIRM' Relay-Forward message from the new AR in step 520, the DS decides to either reply positively (preferably triggering deletion of the old route) or

negatively (preferably triggering deletion of the new route previously added by DR), in step 530.

It is envisaged that the DS replies negatively when it decides that the MN took too much time to switch between ARs. For example, the laptop MN may have entered a sleep mode, or even turned off, in which case the DS denies the CONFIRM because the address was allocated to another new MN in the meantime. Alternatively, when the MN connects to another local-mobility domain, it will CONFIRM this address towards another DHCP Server that doesn't own that address.

If the DS decides to reply negatively to the 'CONFIRM' message in step 530, the DS triggers propagation of a route deletion message to all intermediary routers to the new AR, in step 540. In this manner, all intermediary routers that have just recorded a new route to the MN address, as extracted from the 'CONFIRM' message sent from the AR to the DS, will delete the new route record. In this regard, the DS sends a reply to the 'CONFIRM' message to the MN, via the corresponding AR/DR, to inform the MN, and implicitly the intercepting AR/DR of the negative decision, as shown in step 550.

If the DS decides to reply positively to the 'CONFIRM' message in step 530, the DS removes the old route to the MN assigned address, as stored in its internal routing table as shown in step 560. Substantially concurrently, the DS adds the new route entry to the MN assigned address, where the route indicates the interface through which the 'CONFIRM' message was received, as in step 570. The DS then triggers propagation of a route deletion message to all intermediary routers between itself and

the old AR/DR, in step 580. In this manner, all intermediary routers that have recorded a now obsolete route to the MN address will delete the route record. In this regard, the DS sends a reply to the 'CONFIRM' message to the MN, via the corresponding DR. The reply informs the MN, and implicitly the intercepting DR/AR of the negative decision, as shown in step 550.

In this manner, the DHCPv6 Server is able to allocate the same (CoA) address to the MN, upon the MN moving to a new access router. Advantageously, in this approach, the MN's care-of-address is then maintained as a valid address for the entire micro-mobility domain, irrespective of which access router the MN uses within the domain.

Furthermore, by intercepting the message to the home network, the combination of the new AR/DR and DHCPv6 Server is able to maintain an IP address to the MN, without taking up valuable bandwidth resource in propagating the new route within the micro-mobility domain to higher entities in the network.

A further advantage of this mechanism is that, by provision of a single MN CoA throughout the local mobility (micro-mobility) domain, there is no requirement to perform tunnelling and de-tunnelling operations, which also take up valuable resource (i.e. computing resource on nodes and bandwidth resource on networks).

The inventive concepts of the present invention find particular applicability in mobility-supporting network domains such as a university campus or in a company where nodes are, for example, spread over multiple-storeys in a

building. The topology of such networks is typically a tree-structure with rarely more than three levels in the structure. The mobility population of such domains typically encompass a few hundred nodes. The majority of the communication in these domains takes place among nodes within the domain, and not to an external Internet. Furthermore, local nodes are able to move within the domain. Also, visiting nodes can be accepted to visit and move within this domain quite readily.

Such a domain preferably deploys an Interior Gateway Protocol (IGP) routing protocol, for example a Routing Information Protocol (RIP), as well as a stateful address autoconfiguration scheme such as (DHCP). Thus, within this domain, it is more economically viable to reuse DHCP and RIP functionalities rather than deploying Mobile IP entities, which would require modifying every client PC, every server and introducing home agents.

The inventors of the present invention have recognised that in such a domain, the DHCP server (DS) is never in a situation to refuse a CONFIRM message. Hence, a moving PC will always use the same care-of-address within this domain. This address is its only address and there is therefore never a need to assign a Home Address and a Care-of-Address as is required by Mobile IPv6.

Furthermore, the inventors of the present invention have recognised that a more rapid propagation of route updates can be achieved by continuous triggering of route update messages, for example based on continued use of DHCP messaging. In the context of the present invention, this is achieved by relying on the mandatory and periodic messages of a DHCPv6 CONFIRM message. In alternative

embodiments, such continuous triggering may encompass any regular, periodic or even irregular triggering of route update messages from the two end points.

In this case, a modified operation of the AR/DR in FIG. 4, as well as the DS in FIG. 5, can be implemented. In particular, it is envisaged that both the DS and AR may trigger the route addition to all intermediate routers. Advantageously, such a two-pronged route update triggering mechanism effectively leads to faster updates.

Thus, a mechanism to combine address autoconfiguration with route maintenance, in order to support mobility, has been described. This is in contrast to traditional address autoconfiguration mechanisms, which have been performed entirely automatically and separately from route maintenance. Route maintenance has been performed in a half-manual/half automatic manner, inasmuch as routing information is initially introduced manually in each router and then routers communicate with each other to discover the shortest available routes.

It is to be appreciated that the arrangement and specific details of interfaces, address types, routers, etc. in the above embodiments are merely examples, and the invention is not limited to these examples. The invention should be viewed as capable of being applied to other types of data (computer/communication) networks or protocols and subnets thereof. Furthermore, the invention may also be applied to domains other than a tree-structure or a substantially micro-mobility domain, when such networks have subnets and access networks whose functions correspond to those described above.

The invention, or at least embodiments thereof, tend to provide the following advantages, singly or in combination:

(i) A data packet may be transmitted much more efficiently, with a minimum of number of tunnelling operations performed by intermediary routers, thereby achieving improved route updating.

(ii) When compared to hierarchical Mobile IPv6 schemes, the inventive concepts described above provide:

(a) Bandwidth savings, by eliminating tunnels; and

(b) Elimination of local mobility management entities (e.g. Mobility Anchor Point (MAP)) which have been pending IETF standardization for several years.

(c) Use of the same CoA, avoids updating not only the distant HA but also any new entity, such as a MAP.

(iii) When compared to all other micro-mobility (or local mobility) management schemes, the inventive concepts described above provide:

(a) Inherent configuration flexibility of stateful autoconfiguration, in contrast to other micro-mobility management schemes where the IP address is manually configured;

(b) A more rapid propagation of route updates, by substantially simultaneously triggering from two separate points of the tree, namely the DS and the DR;

(c) A more rapid propagation of route updates, by continuous/regular triggering of route update messages based on continued use of DHCP messaging_

(d) A more rapid propagation of route updates, when changing an access node, by confirmation of an opportunity to re-use the same address using DHCP messaging; and

(e) Compatibility benefits as standard IETF protocols can be used.

(iv) When compared to Cellular IPv6, the present invention does not use any form of paging. Thus, no broadcasting of data is required and a more efficient and less bandwidth hungry solution is achieved. In contrast to Cellular IP, the present invention proposes a "per-host routes" proposal, that notably relies on standard RIP and DHCP as existing, fully specified, software available solutions.

(v) The technique benefits from using the same CoA for the routing of all data packets to a particular mobile node, say within a micro-mobility domain, but with the elimination of intra-domain tunnelling suffered by the mechanism proposed in US005812819A.

Whilst the specific and preferred implementations of the embodiments of the present invention are described above, it is clear that one skilled in the art could readily apply variations and modifications to the preferred embodiments that fall within the inventive concepts.

Thus, a methods to support local mobility in TCP/IP networks and associated network elements have been described, whereby the disadvantages associated with known mechanisms, apparatus and methods have been substantially alleviated.

Claims (PCT)

1. A method of supporting mobility (400, 500) in an Internet Protocol (IP)-based data network, the method comprising the steps of:

generating a first stateful IP autoconfiguration message at a mobile node, wherein said message contains an address capable of use for route maintenance to/from said mobile node;

transmitting, by said mobile node, said generated message to a first access node, where said access node adds its address to said message;

forwarding said generated message, by an access node, to a dynamic host configuration protocol (DHCP) Server; and

analysing said message, at said DHCP server, to determine a route to deliver data to and/or from said mobile node;

wherein the method is characterised by the steps of:

analysing said message, at said access node, to determine a route to deliver data to and/or from said mobile node; and

triggering one or more route update messages from said access node and said DHCP server to a number of network elements (230) between said access node and said DHCP server in the IP based data network.

2. The method of supporting mobility (400, 500) according to Claim 1, wherein the one or more route update messages from said access node and said DHCP server are triggered substantially simultaneously.

3. The method of supporting mobility (400, 500) according to Claim 1 or Claim 2, wherein one or more

route update messages are sent substantially continuously.

4. The method of supporting mobility (400, 500) according to Claim 1, the method further characterised by the steps of:

repeating said steps of generating, transmitting (420) and forwarding for a second stateful IP autoconfiguration message when said mobile node attaches to a second access node;

analysing said second message at said DHCP Server to determine that said second address used for route maintenance in said second message is inconsistent with said first address analysed in said first message; and

triggering a route update message based on said determination.

5. The method of supporting mobility (400, 500) according to Claim 4, the method further characterised by the step of:

transmitting, in response to said determination, a deletion message (540) to said first access node (240) or said second access node (250) and a number of network elements (230) between said DHCP Server (220) and said first access node (240) or said second access node (250), where the deletion message instructs said number of network elements to delete obsolete address information used for route maintenance to/from said mobile node.

6. The method of supporting mobility (400, 500) according to Claim 1, wherein said first and/or second stateful Internet Protocol autoconfiguration message is a DHCPv6 'CONFIRM' message.

7. The method of supporting mobility (400, 500) according to Claim 1, wherein said address information used for route maintenance is based on a distance-vector routing protocol, for example the routing information protocol (RIP).

8. The method of supporting mobility (400, 500) according to Claim 1, further characterised by the step of:

updating route maintenance information by a plurality of nodes in the IP-based data network, for example a DHCP Server (220), an access node such as a DHCP Relay or an Access router (250), and an intermediate router (234).

9. An access node, for example a dynamic host configuration protocol (DHCP) Relay (250) comprising:

a receiving function receiving at least one first Internet Protocol (IP) message from a mobile node, wherein said at least one first IP message comprises a mobile node address capable of use for route maintenance to deliver data to and/or from said mobile node; and

a processor, operably coupled to said receiving function, wherein said processor analyses said at least one first IP message, to determine a route to deliver data to and/or from said mobile node,

wherein the access node is characterised by the processor triggering in a substantially continuous manner a transmission of one or more route update message from said access node (250) to a number of network elements (230) between said access node and a DHCP server in the IP based data network.

10. A dynamic host configuration protocol (DHCP) Server (320) comprising:

a receiving function (325) for receiving at least one first Internet Protocol (IP) message from a mobile node through a first access node, wherein said at least one first IP message comprises a number of addresses used for route maintenance to deliver data to and/or from said mobile node via said first access node; and

a processor (330), operably coupled to said receiving function, wherein said processor analyses said at least one first IP message, to determine a route to deliver data to and/or from said mobile node,

wherein the DHCP Server is characterised by the processor triggering in a substantially continuous manner a transmission of one or more route update message from said DHCP server to a number of network elements (230) between said access node and said DHCP server in the IP based data network.

11. The DHCP Server according to Claim 10, wherein said DHCP Server (320) receives and analyses at least one second IP message comprising a second set of addresses capable of use for route maintenance from said mobile node through a second access node, such that said processor analyses said at least one second IP message to determine whether said second set of addresses are consistent with said first set of addresses.

12. The DHCP Server according to Claim 11, wherein said DHCP Server (320) further characterised by said processor (330), in response to said determination, triggering a route update message to said first access node or triggering a route update message to said second

access node to delete obsolete address information used for route maintenance to/from said mobile node.

13. The DHCP Server according to Claim 10, wherein said at least one first IP message and said at least one second IP message are IPv6 messages.

14. The DHCP Server according to Claim 11, wherein said at least one first IP message and/or said at least one second IP message is an IPv6 stateful autoconfiguration 'CONFIRM' message.

15. The DHCP Server according to Claim 10, the DHCP Server further characterised by:

a memory element, operably coupled to said processor, containing a router table for storing route maintenance information extracted from said first and/or second IP message.

16. A data communication network adapted to incorporate the DHCP Server of Claim 10 or the access node of Claim 9 or adapted to facilitate the method steps of Claim 1.

17. The data communication network according to Claim 16, wherein said first access node and/or said second access node are Access Routers collocated with DHCPv6 Relay functions.

18. The data communication network according to Claim 16 or Claim 17, wherein the data communication network includes a number of routers located between said first access node and/or said second access node and said DHCP Server in a substantially tree-type topology.

19. The data communication network according to Claim 16, wherein a communication link between said mobile node and said first access node and/or said second access node is a wireless access media communication link to facilitate a wireless link.

20. An IPv6 communication message transmitted from a DHCP Server to an access node via a number of routers, wherein the IPv6 communication message comprises route and/or address deletion instructions generated in accordance with Claim 5 or Claim 12.

21. A storage medium storing processor-implementable instructions for controlling a processor to carry out the method according to Claim 1.

22. An apparatus adapted to perform the method steps according to Claim 1.

23. A communication unit comprising apparatus according to Claim 22.

24. A data communication network comprising a communication unit according to Claim 23 or apparatus according to Claim 22.

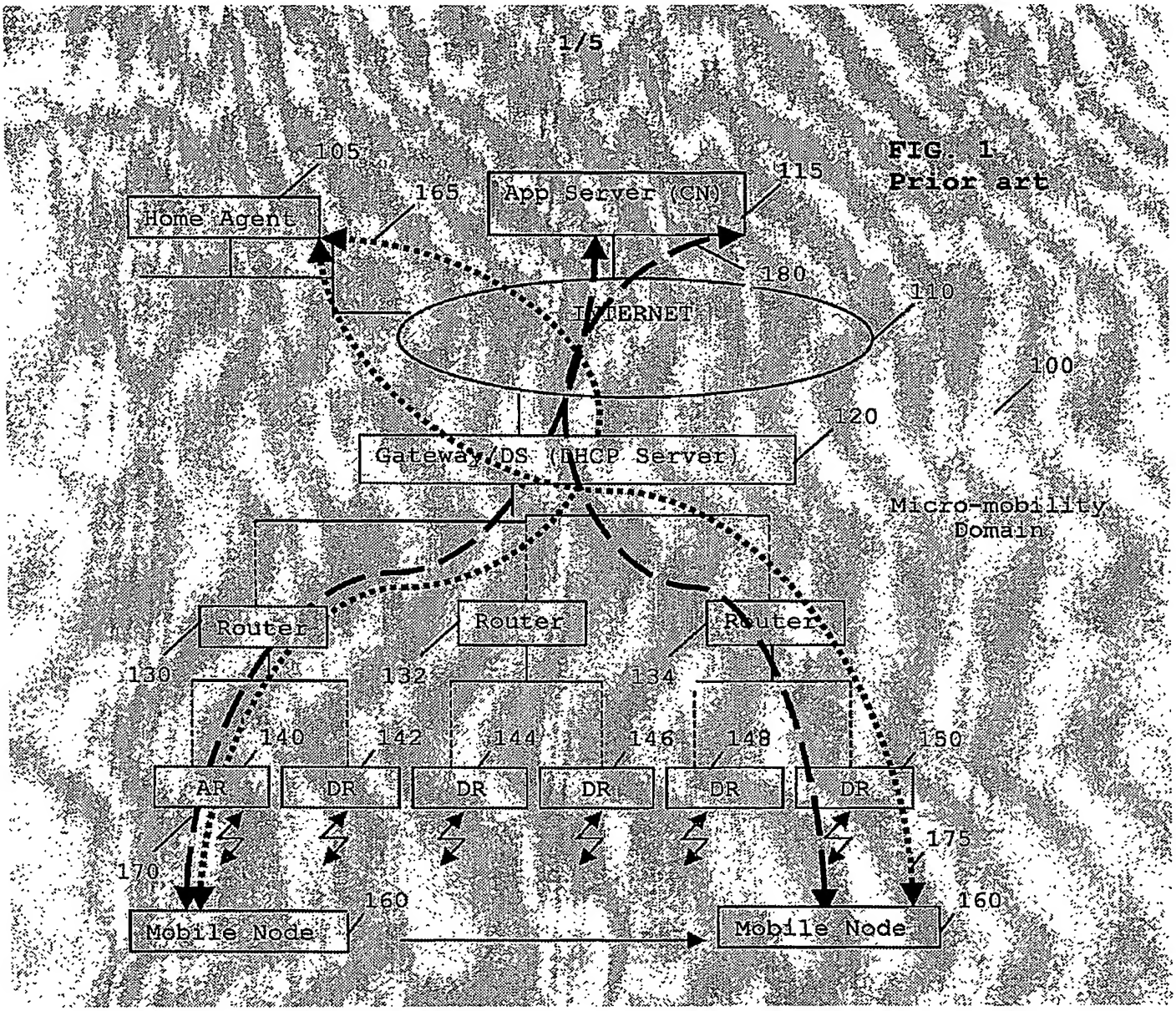


FIG. 1
Prior art

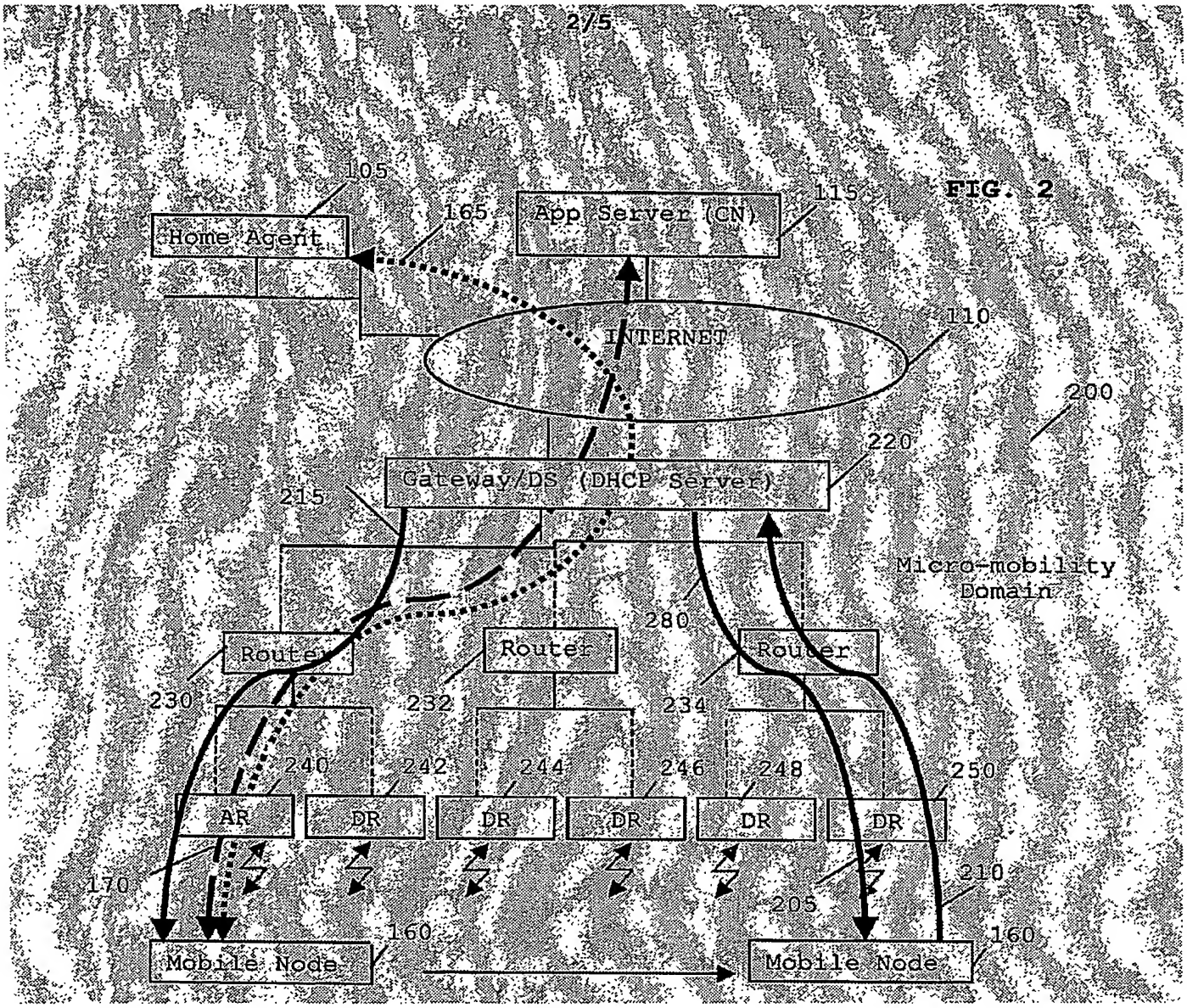

105
Home Agent
165
App Server (CN)
115
INTERNET
110
200
220
Gateway/DS (DHCP Server)
215
Micro-mobility Domain
280
Router
Router
Router
230
232
234
240
242
244
246
248
250
AR
DR
DR
DR
DR
DR
170
205
210
160
Mobile Node
160
Mobile Node

FIG. 2

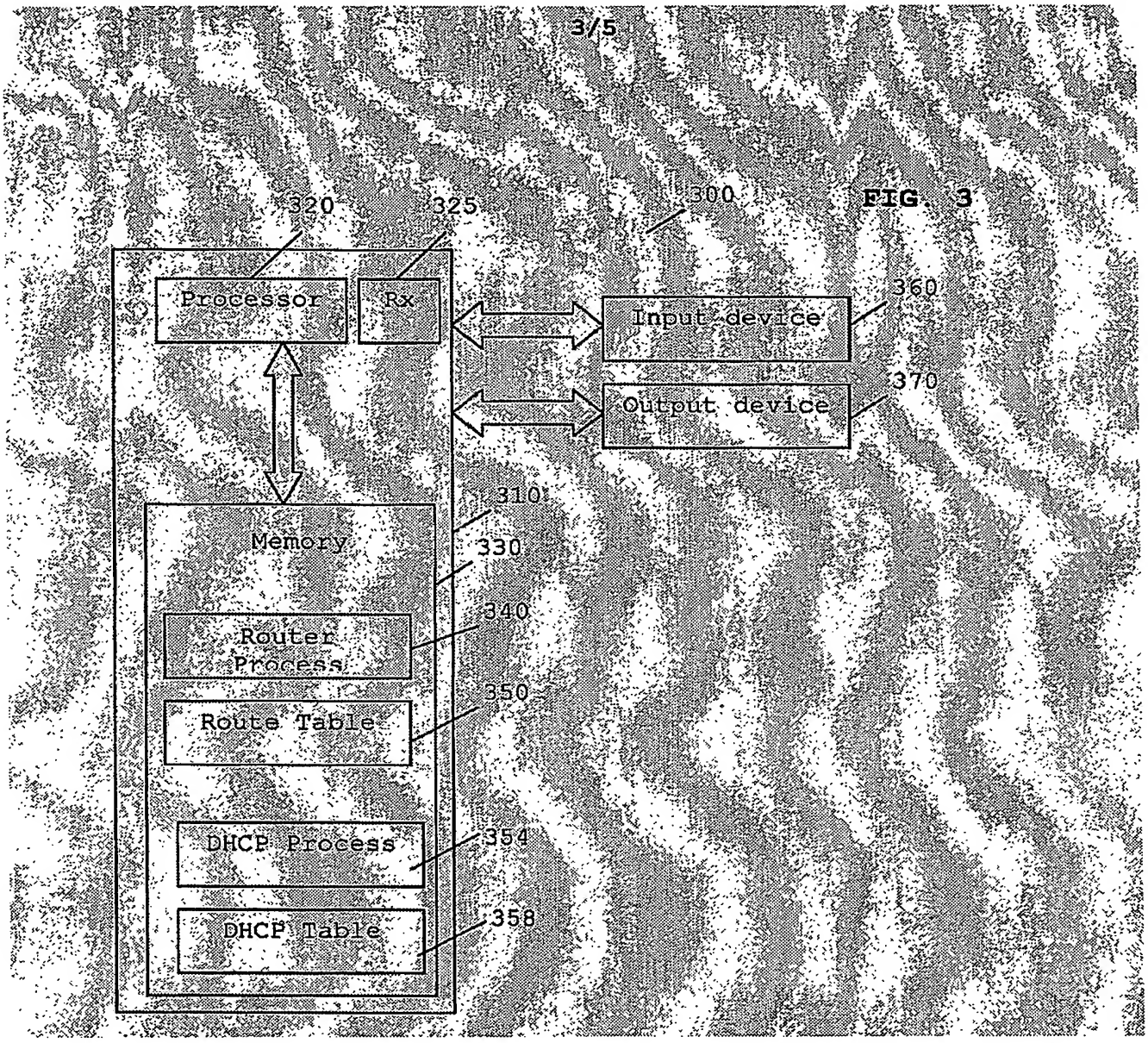

300
320
325
Processor
Rx
Input device
360
Output device
370
310
Memory
330
340
Router Process
350
Route Table
DHCP Process
354
DHCP Table
358

FIG. 3

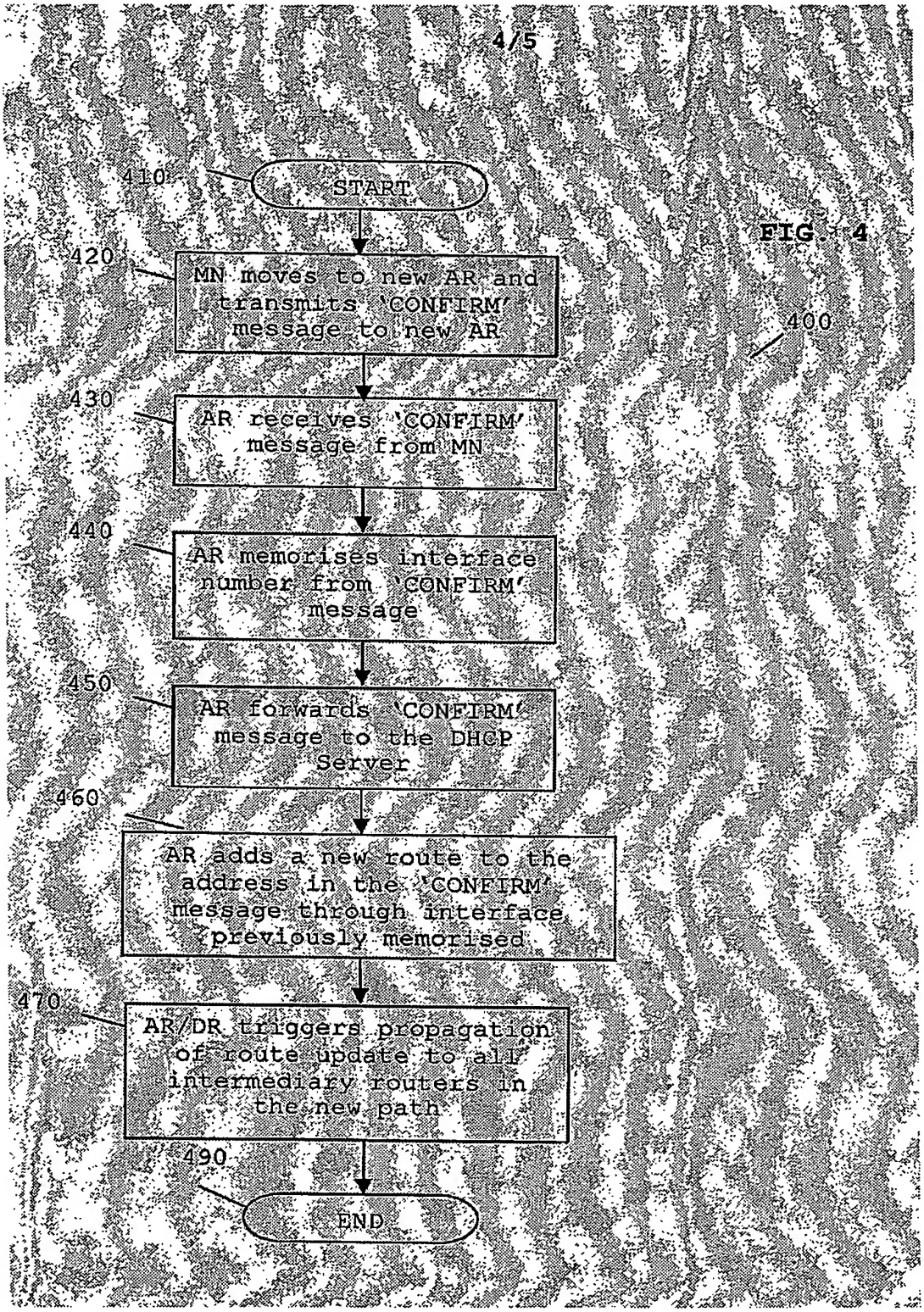

410
START
420
MN moves to new AR and transmits 'CONFIRM' message to new AR
430
AR receives 'CONFIRM' message from MN
440
AR memorises interface number from 'CONFIRM' message
450
AR forwards 'CONFIRM' message to the DHCP Server
460
AR adds a new route to the address in the 'CONFIRM' message through interface previously memorised
470
AR/DR triggers propagation of route update to all intermediary routers in the new path
490
END
400

FIG. 4

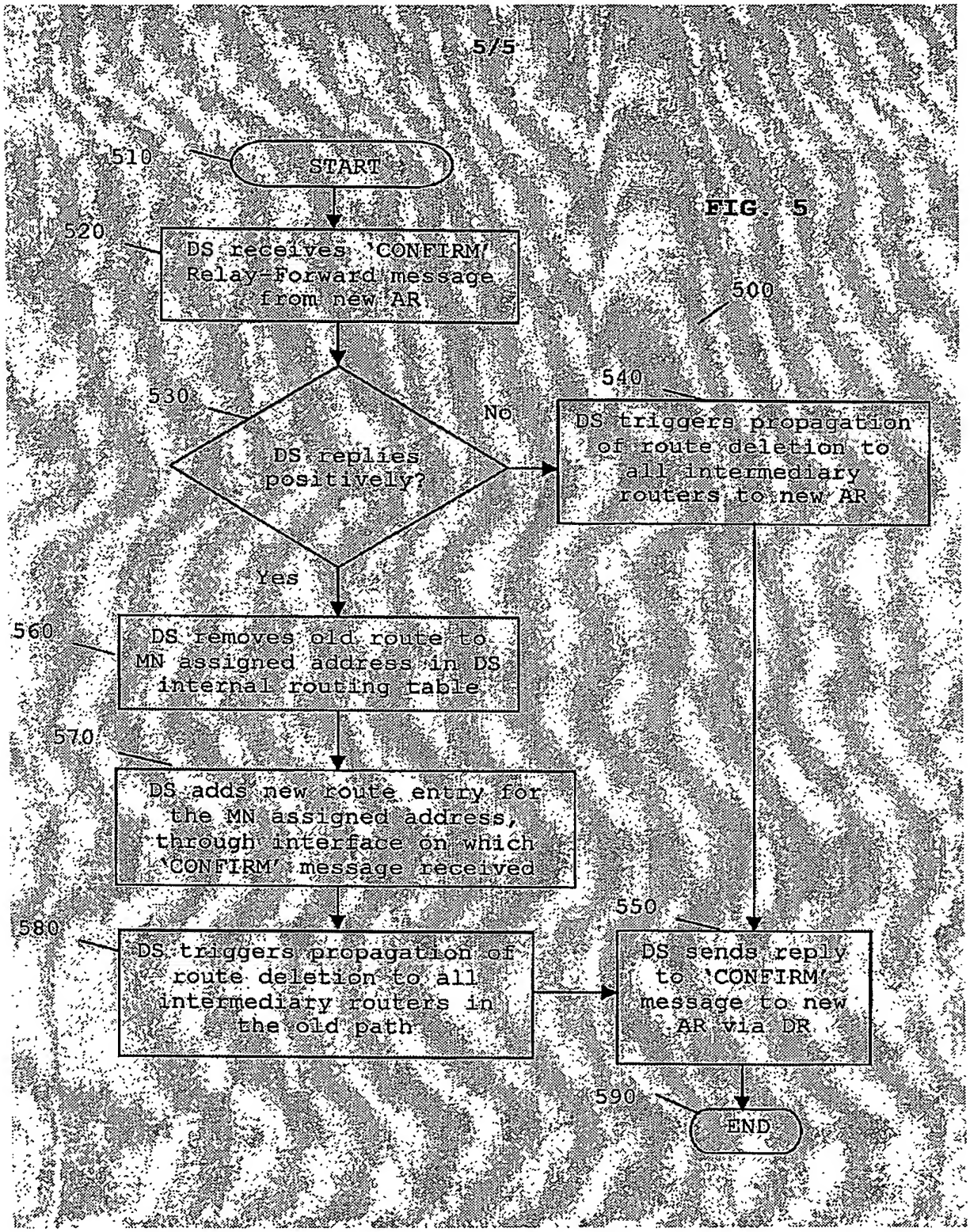

510
START
520
DS receives 'CONFIRM' Relay-Forward message from new AR
500
530
DS replies positively?
No
540
DS triggers propagation of route deletion to all intermediary routers to new AR
Yes
560
DS removes old route to MN assigned address in DS internal routing table
570
DS adds new route entry for the MN assigned address, through interface on which 'CONFIRM' message received
580
DS triggers propagation of route deletion to all intermediary routers in the old path
550
DS sends reply to 'CONFIRM' message to new AR via DR
590
END

FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/50704

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L29/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 011 241 A (LUCENT TECHNOLOGIES INC) 21 June 2000 (2000-06-21)	1,3-24
A	column 1, line 5 - line 9 column 6, line 17 - line 22 column 15, line 17 - line 20 column 16, line 34-52 column 17, line 15-26 column 18, line 6 - line 33 column 20, line 50 - line 57 column 21, line 5 - line 33 column 22, line 6 - line 10 column 22, line 39 - line 50 column 23, line 24 - line 26 column 31, line 18 - line 25 column 32, line 7 -column 33, line 5 column 40, line 28 - line 52 figure 17	2

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 March 2004	17/03/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hes, R

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP03/50704

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1011241 A	21-06-2000	US 6654359 B1	25-11-2003
		CA 2287786 A1	11-06-2000
		EP 1011241 A1	21-06-2000
		JP 2000183972 A	30-06-2000